International Journal of Science Inventions Today

www.ijsit.com
ISSN 2319-5436

Research Article

RESERVOIR CHARACTERIZATION OF AN ONSHORE X-FIELD, NIGER DELTA, SOUTHERN NIGERIA, USING WELL LOGS DATA

Dr. C. O. Aigbogun[1], B.J.O. Mujakperuo[2*] and S. Utah[3]

[1]*Department of physics, University of Benin, Benin City*

[2]*Seplat Petroleum Development Company PLC*

[3]*Department of Earth Science, Federal University of Petroleum Resources, Effurun.*

ABSTRACT

Reservoir characterization is the principal technique commonly employ in the detailed description of any reservoir in order to properly study and analyse the reservoir, which is critical to the field planning and reservoir management in order to maximize recovery through optimal well placement and infill-well.

The X-field is an oil field located in the Onshore Niger Delta. Two sandstones reservoirs (A and B) which extends throughout the field were delineated and correlated, between the depth intervals of 6501.95 ft - 8601.55 ft, using gamma ray log. The trapping mechanisms are fault-assisted (Growth fault) which must have resulted in the lateral variation of thickness and depths of reservoirs across the field. Resistivity log was used to detect the presence of hydrocarbon and the Neutron/Density log, was used to delineate the fluid types present in the reservoirs to be gas, oil and water.

This study reveals the petroleum potential and attempt to make available Petrophysical results for the various reservoirs in three (3) selected wells as these results will help enhance the proper characterization of the reservoirs. The analysis was performed using Schlumberger-Petrel (2015) software.

INTRODUCTION

A reservoir is a subsurface rock that has effective porosity and permeability which usually contains commercially exploitable quantity of hydrocarbon. Reservoir evaluation is undertaken to determine its capability to both store and transmit fluid (Adaeze *et al.,* 2012).

According to John (1994), Reservoir characterization is the development of a detailed understanding of the reservoir, how it is put together and how it reacts to the production strategy. The ultimate goal of an Exploration and Production (E&P) company in the oil industry is to explore and produce hydrocarbon in an economic, safe and environment friendly manner. In other words, the purpose of being in the oil and gas business is to maximize the Net Present Value (NPV) of the asset. As the energy demand of the world continues to grow due to improved standard of life associated with technological advancement and breakthroughs, so also are the challenges associated with exploration and development of new fields, especially because most of the easy-to-find hydrocarbon reserves have already been discovered. As a result, oil exploration has gradually shifted to more challenging environments and thus the need to reduce exploration uncertainty and maximize recovery if supply is to keep up with demand. This need has therefore engendered a multidimensional approach to reservoir evaluation, which combines geophysics, geology, petrophysics, reservoir engineering and geostatistics for detailed evaluation of reservoir properties (Olawale *et al.,* 2018).

Several reservoir characterizing studies have been undertaking, especially to tackle production challenges associated with the complex Niger Delta fields, usually presented with unpredictable stratigraphic and facies variation and oftentimes with related structural complexities. Example of such studies include the work of Weber and Daukoru, (1975), which described the geometry and quality of reservoirs in the Niger Delta based on lateral variation in thickness of reservoirs which is strongly controlled by growth faults, with the reservoirs thickening towards the fault within the down-thrown.

The X-field is a matured field within the Niger Delta whose hydrocarbon content has depleted over time due to constant production from it and has been experiencing some failed well and poor well performance in recently year. Thus, there is a need to approach the study area with more robust interpretation techniques that helps production geologists and reservoir engineers understand reservoir heterogeneities and reduce uncertainties.

Aim and Objectives:

The aim of this study is to characterize the subsurface geology of the onshore X-field, using well log data for proper characterization of the reservoir.

The objectives of this study are to:

1. identify sand units penetrated by the wells.
2. identify reservoir depth and thicknesses across the wells.
3. determine the lateral characteristics of the reservoir through Well correlation.
4. interpret petrophysical parameters.
5. identify hydrocarbon bearing and non-hydrocarbon bearing sands (wet Sands).

Location of Study Area:

The X-field is an onshore field located in the West-Northern part of the Niger Delta Basin, where late Cenozoic Classic Sequence of Agbada formation were deposited in a deltaic fluvio-marine environment (Figure 1).

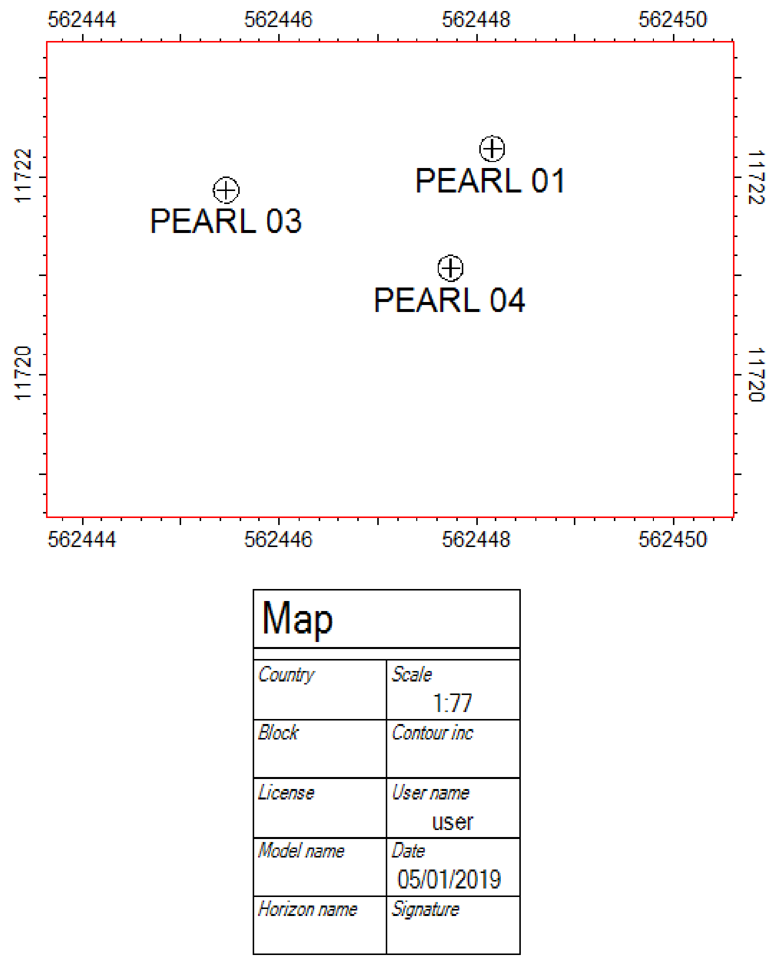

Figure 1: Base map of oil wells in the study area.

LITERATURE REVIEW

Extensive studies of the Niger Delta have been concluded in association with petroleum exploration and exploitation, but most remain proprietary. Most previous studies, focused on local stratigraphic and structural relationships within individual oil fields and concessions. The petroleum geology of the Niger Delta has been described by Tuttle *et al.,* (1999), Doust and Omatsola (1990), Evamy *et al.,* (1978), Weber and Daukoru, (1975) and Short and Stauble, (1967). Allen, (1965), described the recent depositional environments of the Niger Delta. He distinguished four “super environments” and a number of environments and subenvironments that are typical of shelf-delta systems. Oomkens, (1974), also described the recent sedimentation and physiography of the delta.

Summary of the Geology of the Study Area:

X-Field is located in the onshore depobelt of the Niger Delta Basin, where thick Late Cenozoic Clastic sequence of Agbada Formation were deposited in a deltaic fluvio-marine environment. Three main formations (Fig. 2.3) have been recognized in the subsurface of the Niger Delta (Frankl and Cordy, 1967; Short and Stauble, 1967; Weber and Daukoru, 1975; Avbovbo, 1978; Knox and Omatsola, 1989; Tuttle *et al.,* 1999) and these are the Benin, Agbada and Akata formations. These formations were deposited in continental, transitional and marine environments, respectively; together they form a thick, overall progradational passive-margin wedge. This general tripartite lithostratigraphic succession is documented in all deep wells across the Niger Delta.

The Oligocene to Recent Akata Formation is the basal unit of the Niger Delta complex and is composed mainly of dark gray marine shales with some silty beds. The formation is believed to be the main source rock within the Niger Delta complex. According to Jev *et al.,* (1993), the thickness ranges from 2,000 to 20,000 ft (600 to 6,000 m).

The Eocene to Recent Agbada Formation contains most of the petroleum reservoirs in the Niger Delta and consists mainly of alternating sandstone, siltstone and shale. The poorly sorted sandstones are very-fine grained to very-coarse grained and most are unconsolidated to only slightly cemented. Avbovbo (1978), established that the thickness ranges from 9,600 to 14,000 ft (3,000 to 4,200 m).

The Oligocene to Recent Benin Formation largely consists of non-marine sands with a few shally intercalations. Shale content increases towards the base of the formation. Sand intervals are fine to coarse grained. Quartz grains are sub-angular to well- rounded and are white or may be stained brown by limonitic coats. The Benin Formation was deposited in alluvial or coastal plain environments following a southward shift of deltaic environments. The formation is up to 1,000 ft (300 m) thick (Avbovbo, 1978).

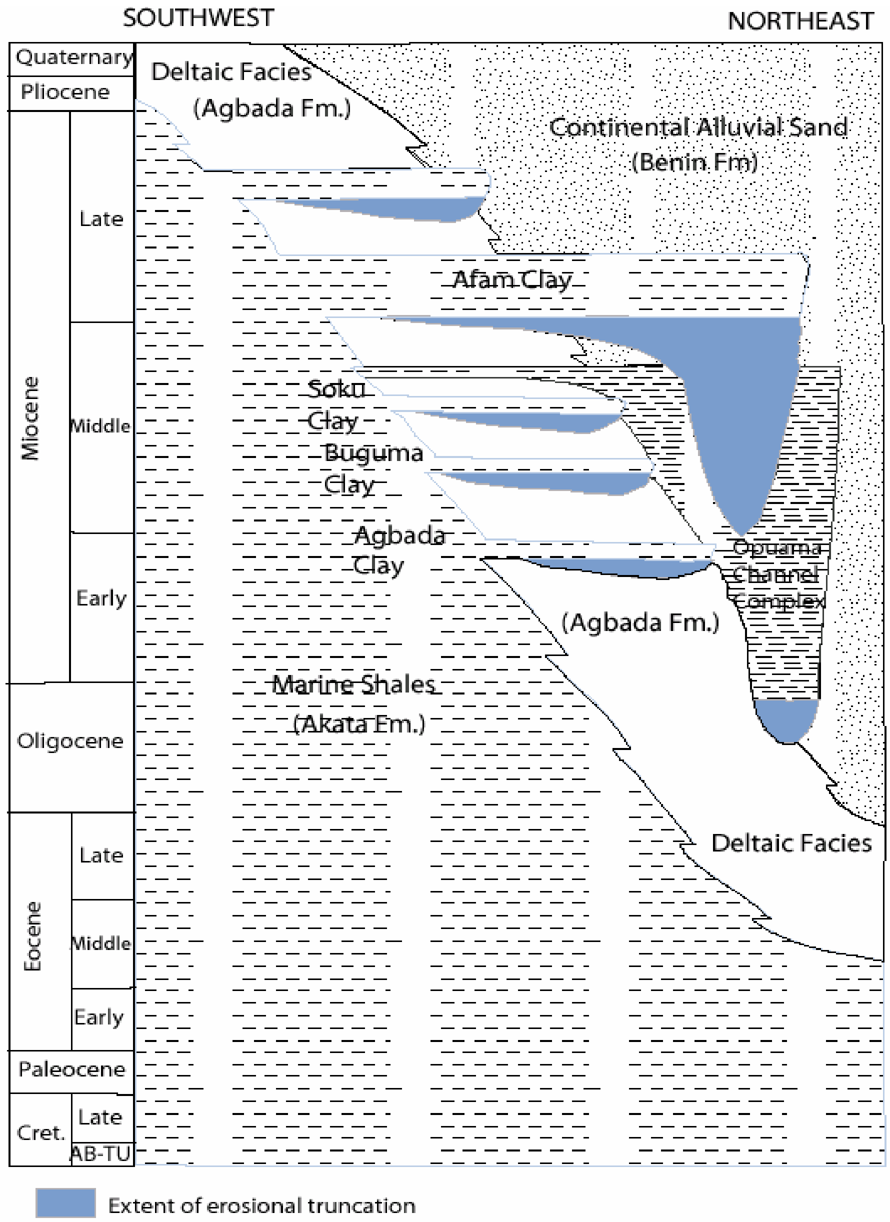

Figure 1: Stratigraphic column showing the three formations of the Niger Delta (Tuttle *et al.,* 1999).

METHODOLOGY

The data used for this research was acquired from Shell Petroleum Development Company via Department of Petroleum Resources (DPR). The data comprises of well logs from three (3) well that were available for the study.

The following data was used to analyse the field using Petrel®2015 software.

1. Well header
2. Deviation data
3. Three composite Well logs

4. Checkshot survey data
5. 5 Formation tops files.

The data were imported into the Software to develop the log models used to analyze the reservoirs in an orderly manner as shown in table 1 below.

No.	DATA	DATA CATEGORY	DATA FORMAT (FILE TYPE)	DATA TYPE	Domain	PETREL Data
1	**Well**	Well headers	Well heads (*.*)	Well	Depth	NotePad, PSPad, WordPad
		Well Paths/Deviations	Well Path /deviation (ASCII) (*.*)	Well	Depth	
		Well Logs	Well Log (ASCII) (*.*)	Well	Depth	
		Checkshots	Checkshots (ASCII) (*.*)	Well	Depth	
2	**Well Tops**	Formation tops	Well Tops (ASCII) (*.*)	Well Tops	Depth	NotePad, PSPad,

Table 1: Petrel Data Types with their File Formats, Categories, Domains and Data Editor

Data type imported into Petrel for modeling is contingent on the intended purpose of the work to be done by the software. For reservoir modeling and petrophysical evaluation of reservoir, all of the data indicated in the table above will be required.

$$IGR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$ ………………………….. Eqn 1.0 (Larionov, 1969).
$Vsh = 0.083 * (2^{3.7IGR} – 1)$ ……………………………………. Eqn 2.0 (Larionov, 1969).
$$\Phi = \frac{\rho ma - \rho b}{\rho ma - \rho f}$$ ……………………………………. Eqn 3.0 (Bob Harrison, 1995).
$Sw = \frac{0.082}{\Phi\_Den}$ ……………………………………. Eqn 4.0 (Udegbunam, et al. 1988).
$$F = \frac{0.62}{\emptyset_D^{\ 2.15}}$$ ……………………………………. Eqn 5.0 (Owolabi *et al.*, 1994).
$Swirr = \sqrt{\frac{F}{2000}}$ ……………………………………. Eqn 6.0 (Owolabi *et al.*, 1994).
$K = 307 + 26552\Phi^2 – 3450(\Phi Swirr)^2$ ……………………………………. Eqn 7.0 (Owolabi *et al.*, 1994).
Sh= (1-Sw) ……………………………………. Eqn 8.0 (Owolabi *et al.*, 1994).
$NTG = \frac{\sum Net\ Sand\ thickness}{Gross\ Sand\ thickness}$ ……………………………………. Eqn 9.0 (Owolabi *et al.*, 1994).

Table 2: Formulae Algorithms used for Petrophysical Evaluation of the X-Fiel

RESULTS AND INTERPRETATION

Reservoir Correlation of the Three Wells:

Correlation of the three wells, reveals that the reservoirs in the X-field are mainly sand and shale formations, with occasional sand-shale intercalation. It also reveals that each of the sand units extends throughout the field and varies in thickness with some units occurring at greater depth than their adjacent unit. It is clear that the area is associated with growth fault which must have resulted to the lateral variation of thickness across wells (figure 2).

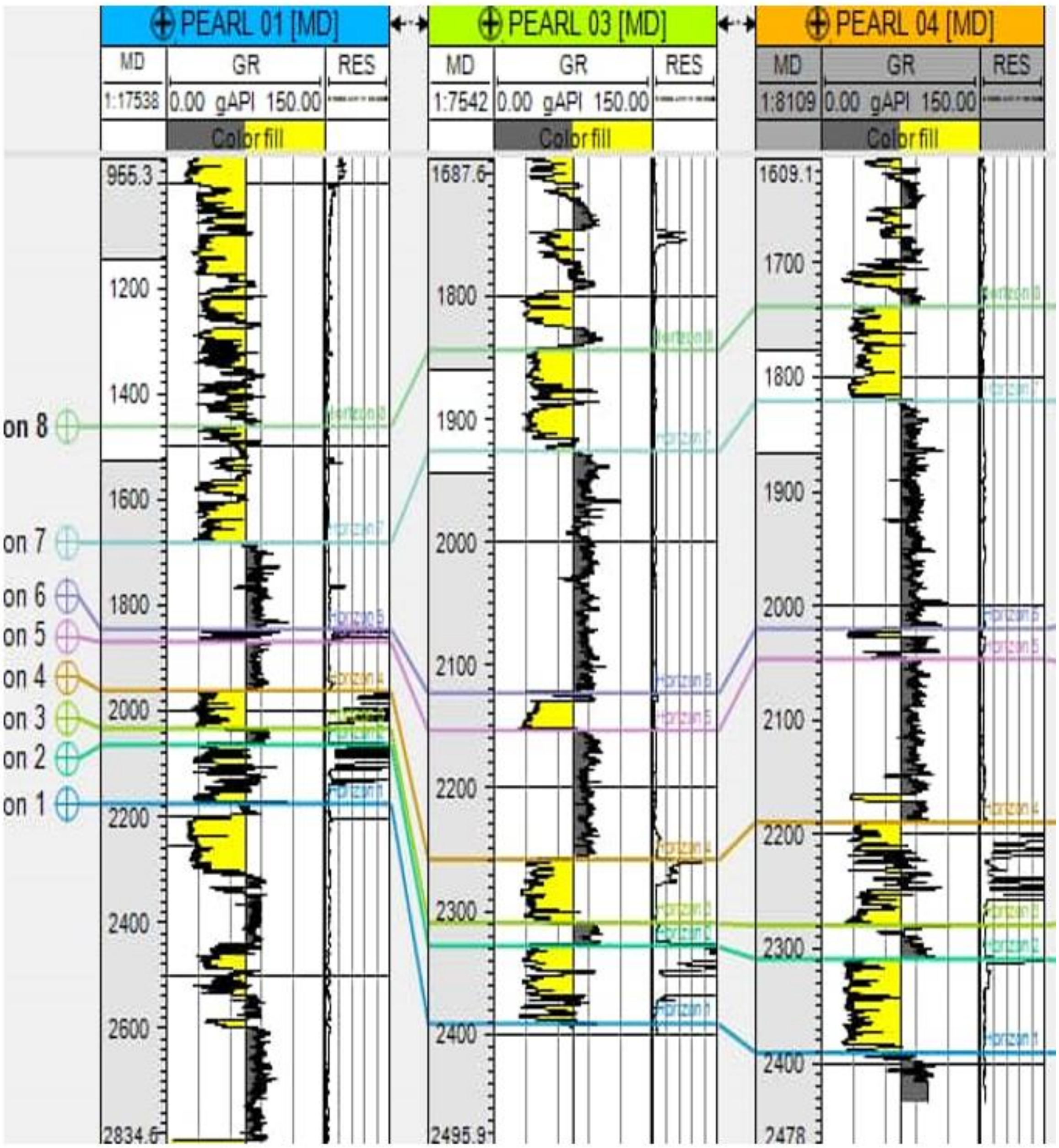

Figure 2: Reservoir Correlation of the three wells (01, 03, 04,) using Petrel 2015 software

Well (Pearl) 04:

The Reservoir, A, in well 04 was delineated with well tops at depth of 2188.55 m (7222.23 ft) as the top of reservoir and at 2277.02 m (7514.17 ft) as the base. Reservoir B was delineated at top depth of 2307.87 m (7615.97 ft) and base depth of 2389.32 m (7884.76 ft) as shown by the well tops markers (Figure 3). The Gamma ray log was a useful tool in determining the lithology at that depth which was considered before selecting the reservoir with high sand thickness, the resistivity log shows a high kick which could represent the presence of hydrocarbon in the reservoir A, and a low kick in reservoir B, which could represent Wet sand.

Also, figure 3 emphasized the use of density-neutron combination tool. As shown, Reservoir A, is a double phase (gas and oil), with a gas capping depicted by the neutron-density separation (balloon shape), while reservoir B is a single phase oil reserve with no visible neutron density separation.

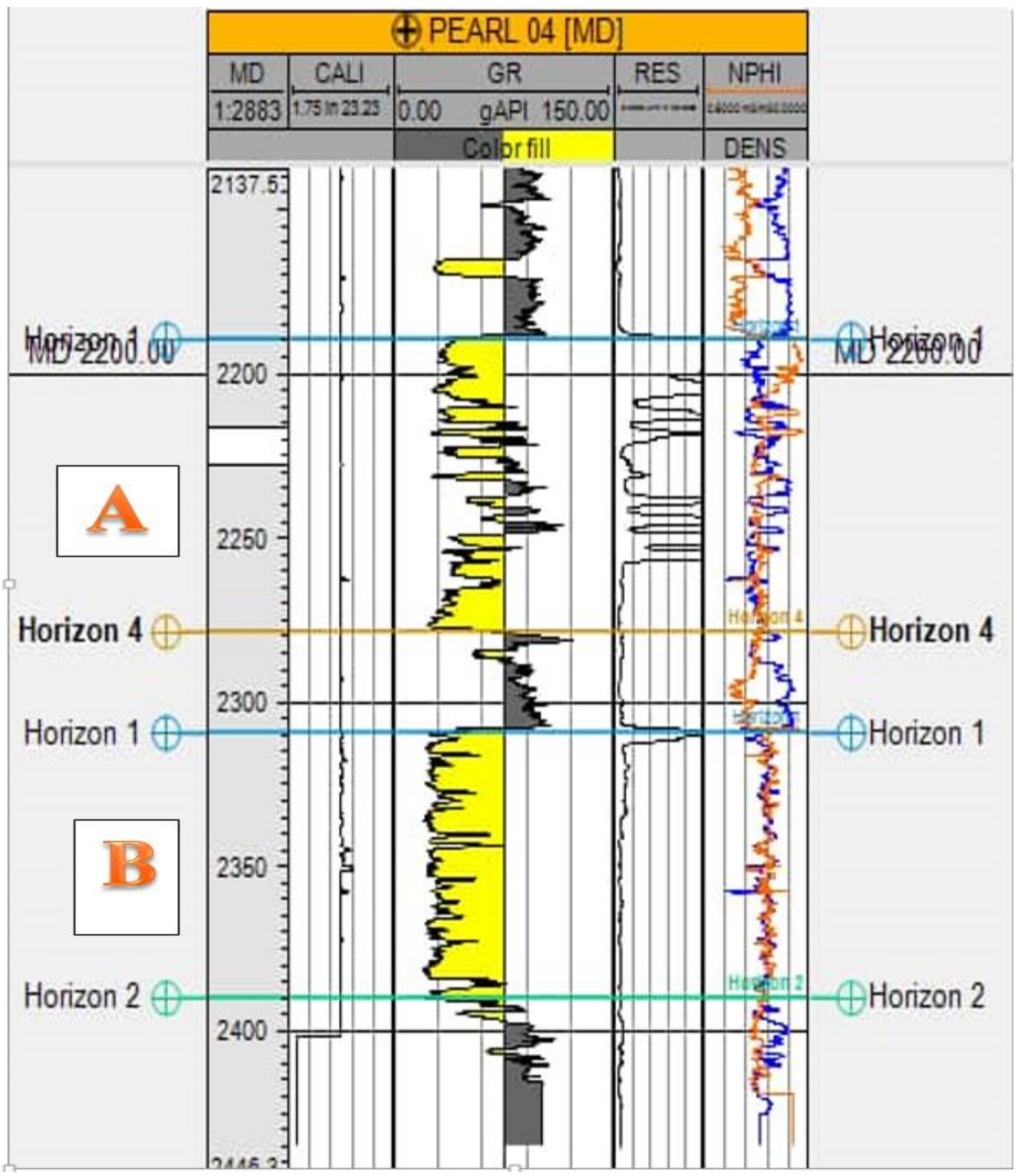

Figure 3: Log Display of Reservoir A and B in well 04, using Petrel 2015 software

Well 03:

The Reservoir A in well 03 was delineated with well tops at a depth of 2257.43 m (7449.52 ft) as the top of the reservoir and base of 2308.71 m (7618.74 ft). Reservoir B was delineated at a top depth of 2327.35 m (7680.26 ft) and base of 2388.61 m (7882.41 ft) as reveal by the well tops markers (Figure 4). The Gamma ray log was used in determining the lithology at that depth which was considered before selecting the reservoir with high sand thickness, with a corresponding high resistivity signature that shows hydrocarbon presence in the reservoirs.

With the help of the density-neutron log, we were able to deduce that both reservoir A and B in well 03 are single phase and they both contain oil as the hydrocarbon fluid type.

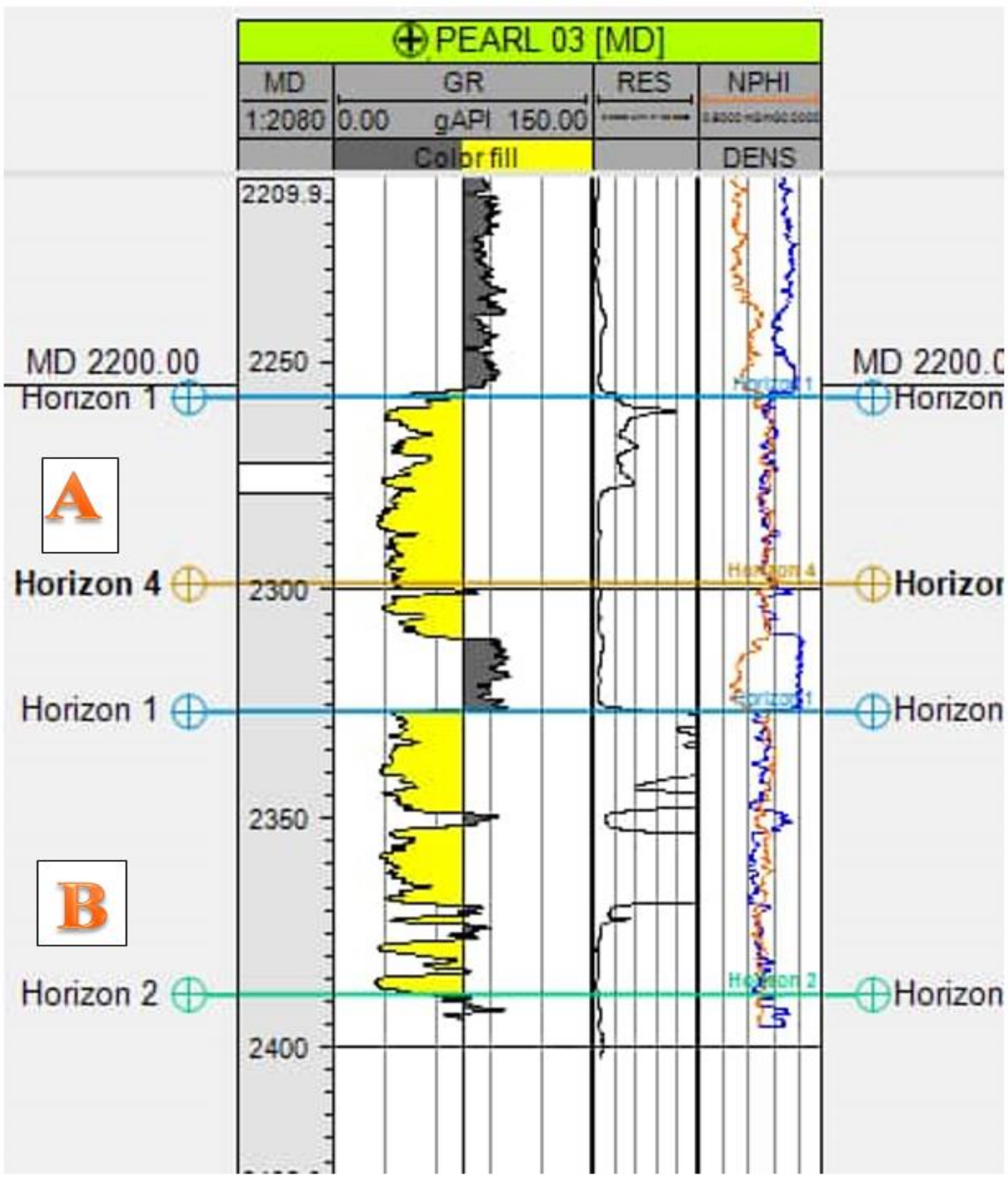

Figure 4: Log Display of Reservoir A and B in well 03, using Petrel 2015 software

Well 01:

Reservoir A is the only reservoir in well 01, which was delineated at a top depth of 1970.29 m (6501.96 ft) and base of 2168.46 m (7155.92 ft). The Gamma ray log was applied in deciphering the lithology of the formation before delineating the reservoir with high sand thickness together with high resistivity signature that indicates hydrocarbon presence in the reservoirs (Figure 5).

Application of density-neutron combination tool enable us to delineate that Reservoir A in well 01, is a double phase (gas and oil), with a gas capping depicted by the neutron-density separation (balloon shape).

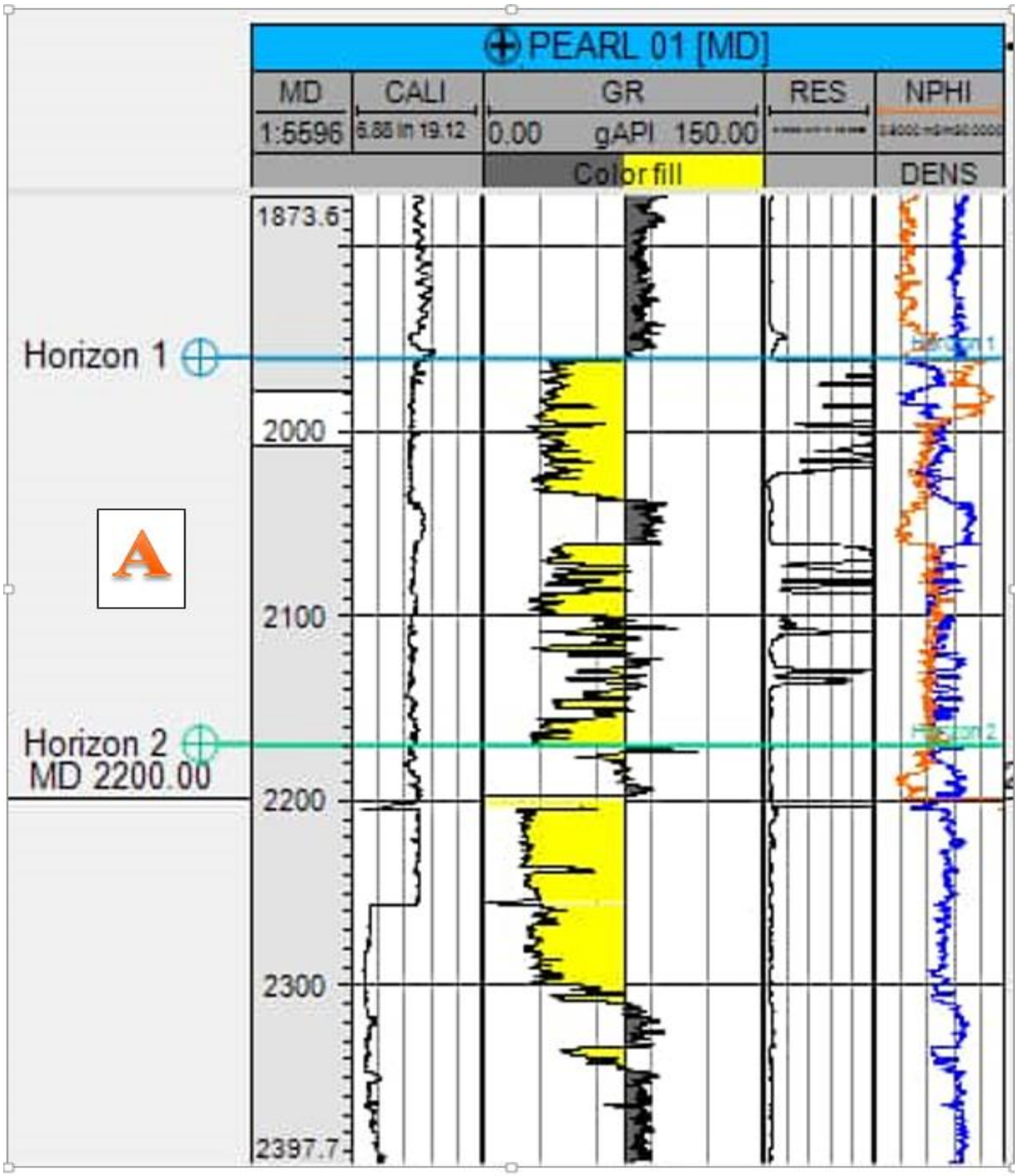

Figure 5: Log Display of Reservoir A in well 01, using Petrel 2015 software

Summary of Petrophysical Properties of the X-Field:

The X-field as summarized in Table 3, has an average gross thickness of 96.11 m (317.16 ft), an average Net Sand thickness of 41.43 m (136.72 ft), an average porosity value of 0.29 (29%), average permeability of 2244.81 mD, an average shale volume of 0.095, Net-to-Gross value of 0.73 (73%) and an average hydrocarbon saturation (Sh) of 0.41 (41%).

From the above mentioned petrophysical properties, we can therefore say that the X-Field is a good hydrocarbon field.

Reservoir	Thickness (ft)	φ	Vsh	eff_{φ}	Swirr	K (mD)	Net S (m)	NTG (M)	Sw	Sh
A (04)	**291.95**	**0.28**	**0.15**	**0.24**	**0.033**	**2150.86**	**25.45**	**0.86**	**0.44**	**0.56**
B (04)	**268.79**	**0.26**	**0.034**	**0.25**	**0.026**	**1980.57**	**76.86**	**0.94**	**0.98**	**0.02**
A (03)	**169.22**	**0.28**	**0.052**	**0.27**	**0.024**	**2196.35**	**40.79**	**0.80**	**0.58**	**0.42**
B (03)	**202.46**	**0.31**	**0.10**	**0.28**	**0.024**	**2515.80**	**20.19**	**0.98**	**0.47**	**0.53**
A (01)	**653.4**	**0.31**	**0.14**	**0.27**	**0.027**	**2380.45**	**43.88**	**0.89**	0.49	0.51
TOTAL	**1585.82**	**1.44**	**0.476**	**1.31**	**0.134**	**11224.03**	**207.17**	**4.47**	**2.96**	**2.04**
			AVERAGE							
	317.16	**0.29**	**0.095**	**0.26**	**0.027**	**2244.81**	**41.43**	**0.89**	**0.59**	**0.41**

Table 4.6: Summary of Petrophysical result of the X-Field

DISCUSSION

The research analysis carried out, reveals that the lithology of the onshore X-field are mainly sand and shale formation with occasional sand-shale intercalation. The sand units delineated, cut-across the entire field at different depths and varies in thickness, which might have resulted from growth fault that is common within the Niger Delta formation (figure 5).

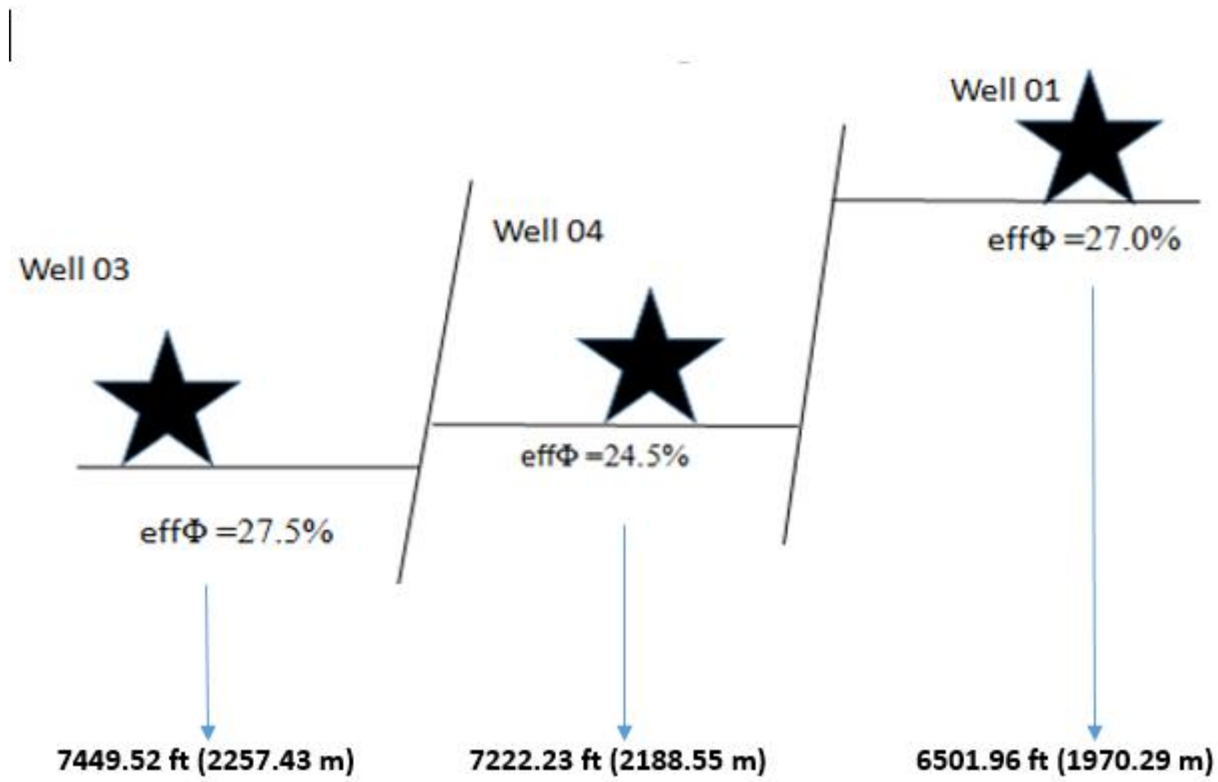

Figure 5: Traverse section of the wells across the field and their respective porosity value and delineation depth

From logs evaluation, prolific sands were encountered at depth range of 6501.95 ft (1970.29 m) to 8601.55 ft (2606.53 m) in the field. The petrophysical parameters of all the wells used in this research exhibited no homogeneity, as shown in table 3 above. The X-field contains both single and double phase reservoirs.

CONCLUSION

Five sand bodies were analyse across the X-field. The quality of any hydrocarbon reservoir is highly dependent on porosity and permeability. With reference to porosity and permeability values estimated by Rider (1986), the porosity and permeability values obtained from the reservoirs of interest are very good and excellent respectively: The high porosity value within the reservoirs zones, exhibit corresponding high permeability which therefore implies, that fluid can flow through the rocks without causing structural changes (Gholami et al., 2012).

This research has also shown clearly that inter-reservoir faults can affect the effective porosity of a given reservoir as depicted by the 0.25 effective porosity value. Therefore, Traverse fault can increase the porosity of one formation and reduce another in a field.

REFERENCES

1. Adaeze, I. U., Samuel, O. O., and Chukwuma J. I, (2012). Petrophysical evaluation of uzek well using well log and core data, Offshore Depobelt, Niger Delta, Nigeria. Pelagia Research Library, ISSN: 0976-8610.
2. Allen, J. R. L., (1965). Late Quaternary Niger Delta, and adjacent areas-sedimentary environments and lithofacies: AAPG Bulletin, v. 49, p. 547-600.
3. Avbovbo, A.A., (1978). Tertiary lithostratigraphy of Niger Delta: AAPG Bulletin, V. 62, p. 295-306.
4. Doust, H., and E. Omatsola, (1990). Niger Delta, in J.D. Edwards and P.A. Santagrossi, Eds., Divergent/passive margin basins: AAPG Memoir 45, p. 201-238.
5. Evamy, B.D., Haremboure, J., Kamerling, P., Knaap, W.A., Molloy, F.A., and Rowlands, P.H., (1978). Hydrocarbon habitat of Tertiary Niger Delta: American Association of Petroleum Geologists Bulletin, V. 62, p. 277-298.
6. Frankl, E.J., and E.A. Cordy, (1967). The Niger Delta oil province- recent developments onshore and offshore: Mexico City, 7th World Petroleum Congress Proceedings, V. 1B, p. 195-209.
7. Gholami, R, Shahraki, A.R and Jamali, P.M, (2012). Prediction of Hydrocarbon Reservoirs Permeability Using Support Vector Machine. Mathematical Problems in Engineering, v. 2012, 18-36.
8. Knox, G.J., and E.M. Omatsola, (1989). Development of the Cenozoic Niger delta in terms of the “escalator regression” model and impact on hydrocarbon distribution, in W.J.M. van der Linden et al., eds., 1987, Proceedings, KNGMG Symposium on Coastal Lowlands, Geology, Geotechnology: Dordrecht, Kluwer Academic Publishers, p. 181-202.
9. Jev B. I., C., Kaars-Sijpesteijn H., Peters M. P. A. M., Watts N. L and Wilkie, J. T., (1993). Akaso Field, Nigeria: Use of integrated 3-D seismic, fault slicing, clay smearing, and RFT pressure data on fault trapping and dynamic leakage. AAPG Bulletin, v. 77, p 1389-1404.
10. Kramers, J.W, (1994). Integrated Reservoir Characterization: from the well to the numerical model, Proceedings, 14th World Petroleum Congress, John Wiley & Sons, 1994.
11. Olawale O.O., Janet O. A., Christiana P.N., Ekeng O. M.., Taiwo O. B, (2018). Reservoir description and characterization of Eni field Offshore Niger Delta, southern Nigeria. Journal of Petroleum Exploration and Production Technology, V 8, Issue 2, pp 381–397.
12. Oomkens, E., (1974). Lithofacies relations in late Quaternary Niger Delta complex: Sedimentology, v. 21, p. 195-222.
13. Short, K.C., and A.J. Stauble, (1967). Outline of geology of Niger Delta: AAPG Bulletin, V.51, p. 761-779.
14. Tuttle M.L.W., Charpentier R.R. and Brownfield M.E., (1999). The Niger Delta petroleum system: Niger Delta Province, Nigeria Cameroon, and Equatorial Guinea, Africa, USGS Open-File Report 99-50-H.
15. Weber, K.J., and E.M. Daukoru, (1975). Petroleum geology of the Niger Delta: Proceeding of the Ninth World Petroleum Congress, Tokyo, V.2, p. 209-221.